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THE RELATIONSHIP OF MOISTURE TO COTTON QUALITY PRESERVATION AT GINS

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INTRODUCTION

The hygroscopic nature of the raw cotton fiber is responsible for much of cotton's performance during ginning and spinning. Several physical properties of cotton fibers depend directly on moisture content. Among these properties are shape, size, flexibility, and tensile strength. Tensile strength is of special importance in ginning. Flexibility is also important but to a lesser extent.

EARLY RESEARCH

The general relationship of tensile strength to fiber moisture content is well known because various aspects of this relationship have been studied by many researchers. Recent work by the U.S. Cotton Ginning Research Laboratory at Stoneville on the preservation of cotton's inherent length distribution during ginning showed that the tensile strength of raw cotton fibers increases as moisture content increases but the force required to separate fibers from their seed does not increase and may even decrease under certain conditions (fig. 1).

Another experiment in this study showed that at the 7-percent fiber moisture level, the force required to separate fibers from their seed is only about 55 percent of their tensile strength, or conversely, the mean fiber tensile strength is about 1.8 times the fiber-seed separation force (table 1). The principal conclusion that can be drawn from these data is that as seed-cotton is dried, the ratio of tensile strength to fiber separation force is reduced, and the likelihood that any individual fiber will break before normally separating from its seed is increased. It was further concluded that although gin-drying processes create a situation conducive to fiber breakage, controlled drying or restoring moisture to dry fibers results in ginned lint having greater end use value than if it is ginned with uncontrolled drying systems or with fiber moisture content lower than that required for satisfactory gin operation and smooth preparation.

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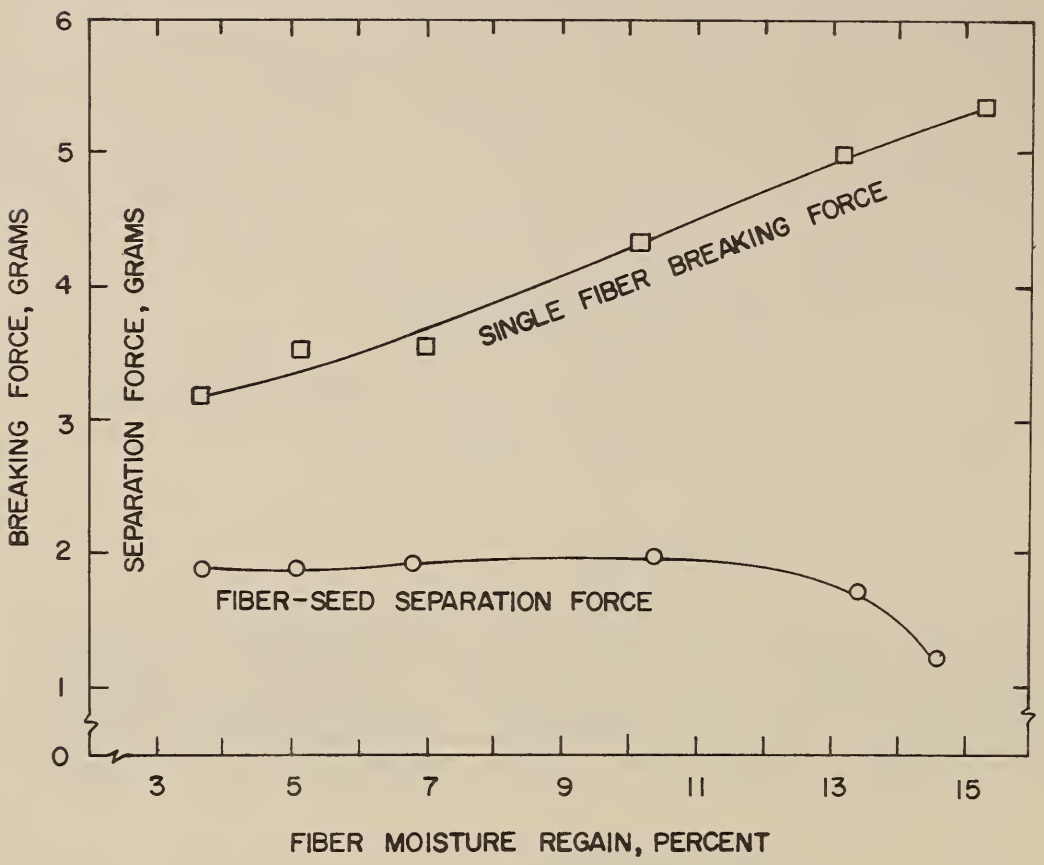

Figure 1. The effect of moisture content on single fiber breaking force and fiber-seed separation force.

Table 1. Relationship between fiber-seed separation force and tensile strength for 100 individual fibers of four popular cotton varieties[1/]

[Fibers had a moisture content of 7 percent]

Cotton variety and statistical item	Fiber-seed-separation force	Single fiber breaking force	Ratio of separation force to breaking force	Ratio of breaking force to separation force
	Grams	Grams		
Pima S-1:				
Range	1.0 - 5.3	1.3 - 7.7	--	--
Mean	2.2	4.2	.52	1.91
Acala 1517C:				
Range	1.0 - 4.2	1.5 - 8.3	--	--
Mean	2.3	4.1	.56	1.78
DPL 15:				
Range	1.0 - 3.7	1.3 - 8.4	--	--
Mean	2.1	3.8	.55	1.81
DPL Smoothleaf:				
Range	1.0 - 4.2	1.6 - 7.1	--	--
Mean	2.0	3.6	.56	1.80

1/ Ten fibers longer than 1 inch from each of ten seeds.

Preservation of fiber length and length distribution during ginning requires proper control of the moisture content of cotton fibers and results in controlling the degree of fiber tensile breakage. One of the objectives of the ginning research laboratories is to make the best possible use of this information in developing machinery and methods for ginning cotton that will best serve the cotton industry.

During early days of cotton drying, not enough attention was given to the effect of drying on fiber degradation. Driers prevented rough preparation, and this was a great boon to the industry. These driers were heated by steam, and 160° to 180° F. was about the maximum temperature that could be obtained. If the cotton was fairly dry, drying did not materially affect fiber properties that were measured in those days. With the advent of high-capacity heaters, having at first 500 thousand, then 1 million, and now 3 million B.t.u. output, noticeable adverse effects became apparent. At the same time that heater capacities were increasing, seed cotton cleaning machinery in gins was becoming more elaborate, and fiber testing technology was improving.

Table 2 shows some of the first work done to show the relationship between moisture and fiber properties in ginning. Moisture content of the lint

Table 2. Effect of drying to various moisture levels on selected quality elements

Item	Temperature - degrees F.			
	180	220	265	350
Lint moisture content---------percent	6.5	5.6	5.2	4.7
Lint grade----------index	89	91	92	92
Upper half mean length---------inches	1.10	1.09	1.08	1.07
Lint foreign matter content---percent	6.0	5.3	4.8	5.3
Manufacturing waste----------percent	11.7	10.8	10.1	10.5
Yarn strength, 22's----------pounds	103	101	101	100

ranged downward as temperature increased, and the higher the temperature, the lower the final moisture content. This relationship will hold for any ginning system. Because the amount of drying is dependent upon initial cotton moisture content, exposure, and temperature, and because no two gins are quite alike, no effort has been made to develop a fixed relationship between drying air temperature and fiber moisture content because it would be valid for only one set of conditions. Furthermore, with the development of the electronic

moisture meter there is no need to try to do so since recommendations can now be given in terms of moisture content of the lint, and the necessary measurement can be made within a few seconds with a moisture meter.

These early tests showed that as moisture content decreased, the resulting lint grade usually improved (table 2). The upper half mean length was reduced 0.03 of an inch when moisture changed from 6.5 to 4.7 percent. Manufacturing waste dropped about 1 percentage point because foreign matter was more efficiently removed at the low moisture level. This is also indicated by the Shirley Analyzer tests. Yarn strength declined as the moisture content was reduced.

These early studies were subsequently expanded to cover a wide range of conditions and to provide sufficient data to discover trends for fiber properties at various lint moisture contents. Drying seed cotton from 10 to 4 percent showed that the gin cleaning machinery became more efficient, and consequently, the lint grades improved as the moisture content decreased (fig. 2). Because of fiber breakage during the ginning processes, the upper half mean length declined steadily as moisture declined from 10 to 4 percent (fig. 3). This length reduction was reflected in yarn strength, which also declined in direct relationship to moisture content (fig. 4).

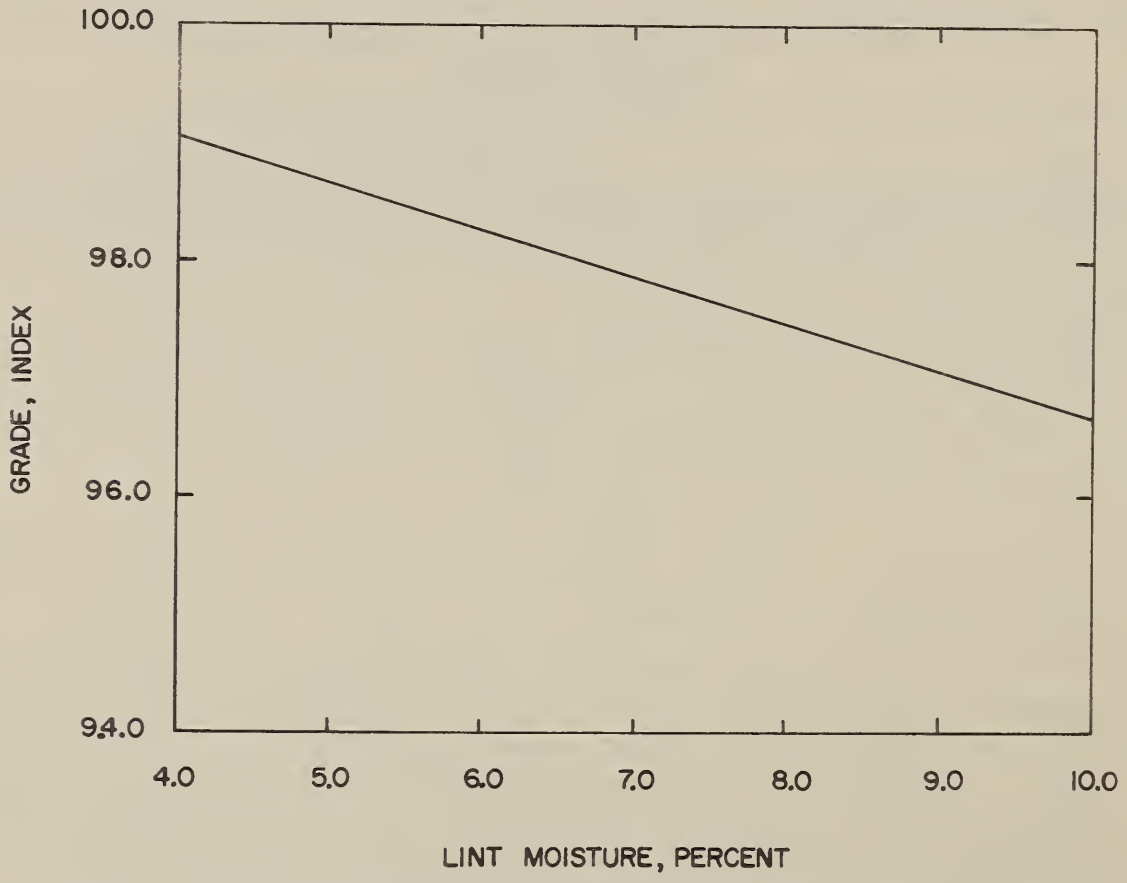

Figure 2. Effect of drying to various moisture levels on grade.

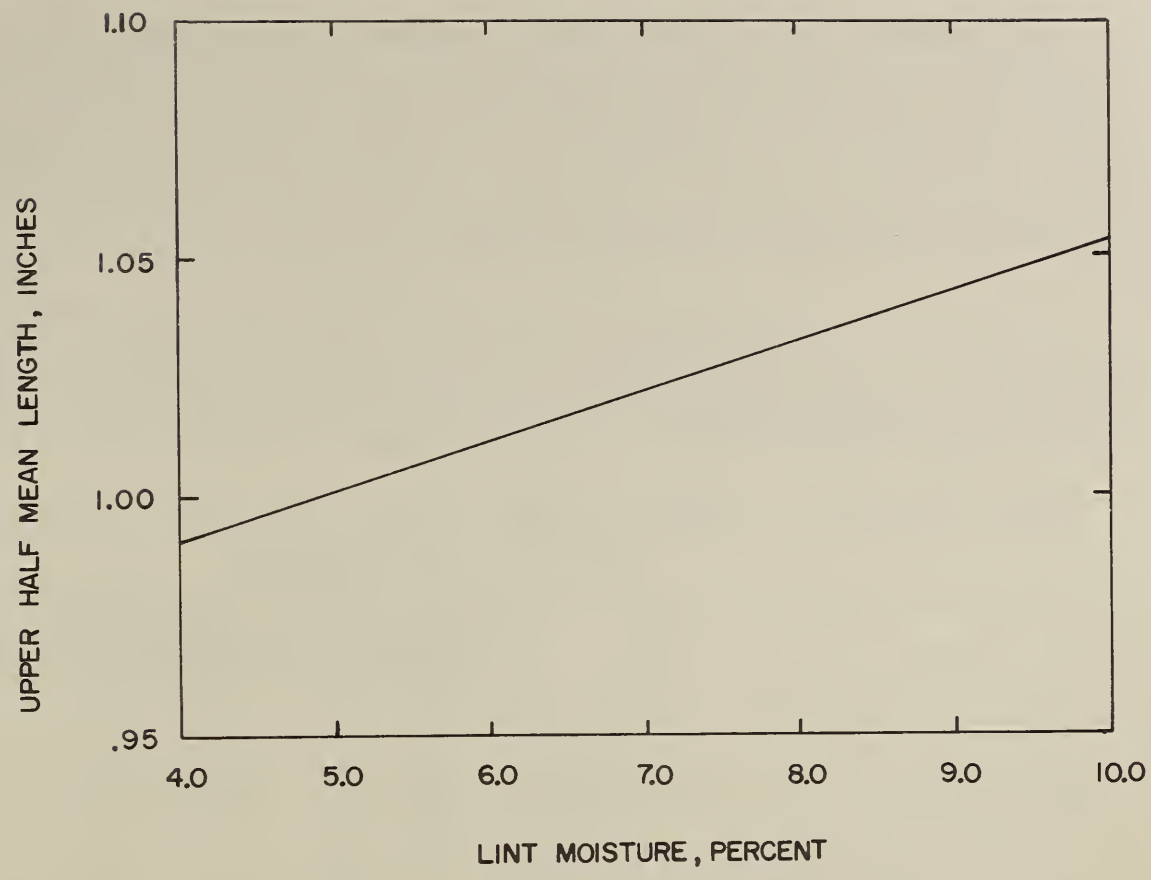

Figure 3. Effect of drying to various moisture levels on length.

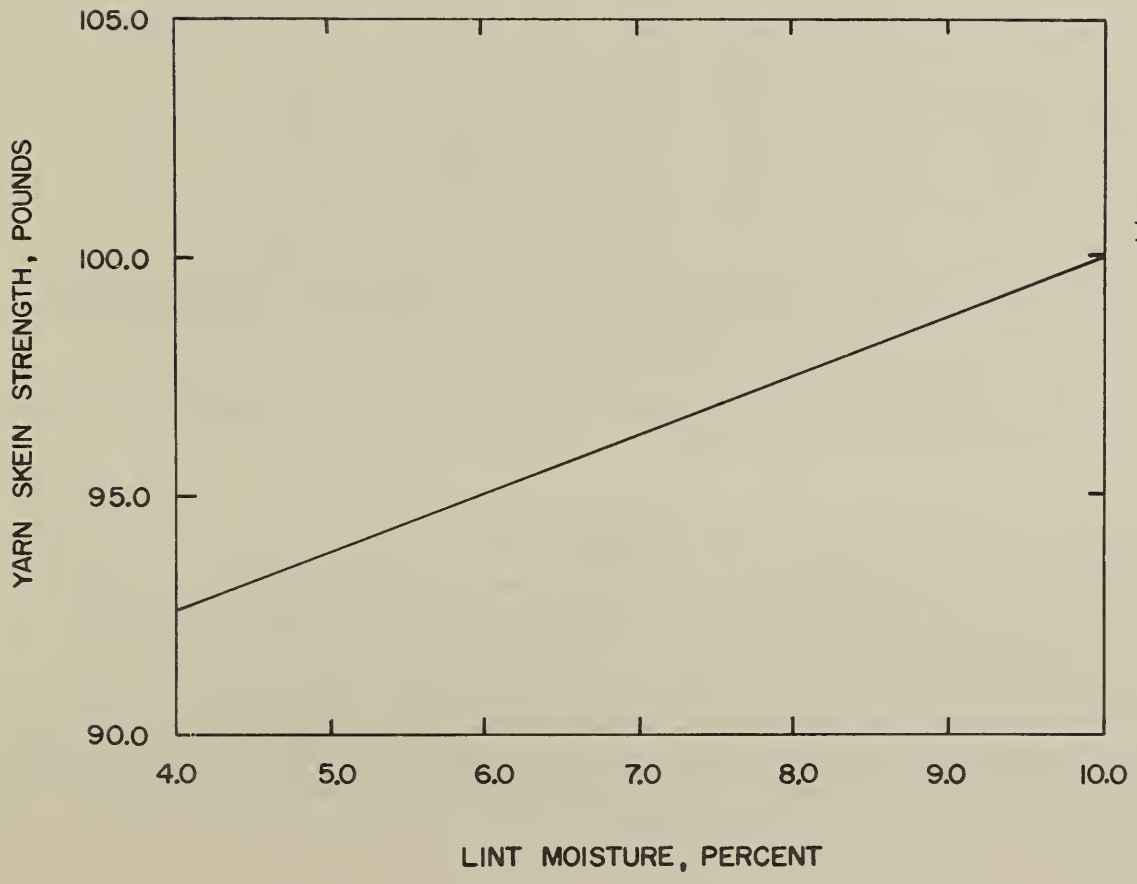

Figure 4. Effect of drying to various moisture levels on 22's yarn strength.

During the time the previously mentioned studies were conducted, gins were using one lint cleaner and 18 to 24 cylinders of seed cotton cleaning machinery. Farmers were disturbed about the low turnout. When the cotton was dried to a low level to obtain relatively good grades, the bale weight was quite disappointing. In an effort to compensate for weight losses caused by overdrying, some ginners tried adding moisture to the fiber just before baling to give it a content of about 7 percent.

The practice of adding moisture to the lint had been used for some years in the West to control static electricity, but the U.S. Cotton Ginning Research Laboratory at Stoneville found it to be of no value insofar as fiber property preservation was concerned. The upper half mean length and yarn strength were virtually unchanged by the lint slide moisture addition (table 3). As a

Table 3. Effect of adding moisture on the lint slide on various cotton quality elements

Item	Without drying	Drying plus	
		No moisture	Moisture
Lint moisture----------percent	8.6	4.6	9.0
Lint grade----------index	76	91	88
Staple length----32ds of an inch	34	33	33
Upper half mean length----inches	1.08	1.00	1.02
Manufacturing waste------percent	14.5	10.0	11.2
Yarn strength 22's--------pounds	113	105	99

result of these studies, the ginning research laboratories have never recommended that moisture be added to cotton at the lint slide in the rain-grown areas. The only justification for adding moisture at this point is to neutralize static electricity to allow the gin to operate. It will be noted that none of the elements of quality listed in table 3 were enhanced by the addition of moisture at the lint slide.

During this same period, studies were underway at the U.S. Cotton Ginning Research Laboratory, Stoneville, to determine whether there was some way to utilize the drier to help make cotton cleaning more efficient and yet preserve fiber properties. In a series of studies on machine-picked cotton carried out in four replications, a mass of cotton was dried to a moisture content of 3.7 percent and divided into two lots. One lot was ginned immediately; the second lot was stored for 1 week prior to ginning to allow the cotton to reach moisture equilibrium. The differences between the lots that were ginned immediately and those that were allowed to regain their

moisture prior to ginning were quite marked (table 4). The lint grades were approximately the same for both lots, but the lot that had regained moisture had one thirty-second of an inch longer staple and yarn strength was substantially higher (table 4). From these tests it was assumed that the ginner could "have his cake and eat it too." It appeared that cotton could be overdried to obtain high grades, then could be moistened before ginning to prevent fiber property degradation associated with overdrying and to preserve the spinning quality.

Table 4. Effect of moisture regain on cotton properties[1/]

Item	Ginning conditions	
	Dried and ginned immediately	Dried and stored for 1 week prior to ginning
Lint moisture----------percent	3.7	7.0
Lint grade----------index	87	86
Staple length---------32ds of an inch	32.7	33.6
Upper half mean length---------inches	1.00	1.03
Upper quartile length----------inches	1.15	1.20
Yarn strength:		
22's----------pounds	107	111
36's----------pounds	56	61
60's----------pounds	29	31

1/ Average of four replications on machine-harvested cotton.

To prove or disprove the foregoing assumption, equipment was constructed and tests were carried out according to the procedure that follows. Cotton was dried in the conventional manner, and moisture in the form of a spray was added prior to ginning.

The results of these studies, which were carried out in three replications show that the lint moisture content prior to drying averaged 6.9 percent, after drying 3.7 percent, and when moistened just before ginning, 5.7 percent (table 5). The cotton that was dried contained 1.2 percent less foreign matter than the undried cotton. This was reflected by an increase in grade and a reduction in manufacturing waste. The upper half mean length, staple length, and yarn strength values of the dried cotton were typical compared to those of cotton ginned without drying. When 2 percent moisture was added to the dried cotton, bringing the lint moisture content up to 5.7 percent, the

measurable fiber properties did not appear to be affected by drying. The upper half mean length, staple length, and yarn strength of the "dried plus moisture added" all compared favorably with these measures from the undried cotton. Lint grade, however, was also the same for both treatments. This was rather disappointing in that it seemed to indicate the correctness of the old adage that "one cannot have his cake and eat it too."

Table 5. Effect of moisture restoration prior to ginning on various quality elements[1/]

Item	Without drying	Drying plus --	
		No moisture added	Moisture added before ginning
Lint moisture----------percent	6.9	3.7	5.7
Lint foreign matter content--------percent	7.4	6.2	6.7
Upper half mean length----------inches	1.06	1.02	1.06
Lint grade----------index	86.6	89.6	86.6
Staple length----------32ds of an inch	34.2	33.6	34.3
Manufacturing waste----------percent	12.4	11.7	11.7
Yarn strength:			
22's----------pounds	114	109	115
50's----------pounds	40	37	39

1/ Average of three replications.

Although the cotton had been overdried, some moisture had been restored, and apparently the fiber and spinning performance had been preserved, yet the grade, which is the farmer's yardstick of quality, had not been improved (table 5). Based on these and other similar results, the U.S. Cotton Ginning Research Laboratory, Stoneville, Miss., never recommended the practice of overdrying cotton and adding moisture prior to ginning. There was no benefit to the farmer, and all of these extra processes add to the costs of ginning. The samples tested did not reveal irreversible damage, but this does not preclude the possibility that irreversible damage did occur that may cause inferior performance during some phase of manufacturing.

Because of the results obtained from the previously described studies, attention was directed to the development of control systems for gin drying and to recommendations for the ginning industry for preserving the spinning performance of cotton. These recommendations have been widely publicized in papers by various staff members of the ginning research laboratories, specialists in the Federal and State Extension Services, the American Textile Manufacturing Institute, the National Cotton Council, and various State organizations. As a result of research, control systems are now on the market that can prevent overdrying in gins. If these control systems are operated properly and the recommended amount of cleaning equipment is used, farmers will obtain satisfactory grades, and the spinner will obtain cotton having good properties.

During recent years equipment has been developed for restoring moisture to cotton that arrives at the gin with less than optimum moisture. This is typical of a large portion of the crop in the West and of an estimated 25 to 50 percent of the crop in the rain-grown areas.

There are two commercially available methods for adding moisture to cotton after cleaning and prior to ginning. One method uses high-humidity air, and the other uses a very fine water mist spray similar to that used in early tests by the U.S. Cotton Ginning Research Laboratory at Stoneville.

In cooperation with the pilot plant at Clemson, S. C., tests have been made using these two moisture-restoration methods for 2 consecutive years. Spinning tests on the first series of this cotton have been completed. The lint averaged 5.7 percent in moisture content as it came from the field (table 6). This cotton did not need drying because it was below the recommended moisture level for ginning. However, for this test it was dried to 2.8 percent moisture content, and then the moisture was restored to 3.3 percent using high-humidity air and to 5.5 percent using a spray. Increasing the moisture content to 3.3 percent with the vapor did not affect cleaning efficiency of the moting system nor of the lint cleaners. Increasing the moisture content to 5.5 percent by spray did reduce the efficiency of the lint cleaning machinery as reflected by a slight increase in lint foreign matter content for the sprayed lots. This was relatively clean machine-picked cotton, averaging 2.9 percent foreign matter in the lint before drying and 2.2 percent after drying. Grade before drying averaged SLM, and full grade improvement was realized by drying. This grade increase was maintained with the vapor treatment, but the grade of the sprayed lots was the same as it was for the cotton prior to drying. These results are identical with findings from the early tests previously described. Failure to maintain grade improvement is the reason the ginning research laboratories have never recommended heavy drying followed by moisture restoration for ginning. However, it is safe to say that if the lint moisture had been raised to only 3.5 or 4.0 percent (table 6), grade improvement would have been realized because there would not have been sufficient moisture present to reduce the cleaning efficiency of the gin stand and lint cleaners. There is nothing technically wrong with adding moisture to cotton with a spray, but it is easy to add too much and thus reduce the potential grade.

Table 6. Effect of drying and moisture restoration on selected fiber properties

Item	Treatment			
	No drying	Dried	Dried plus vapor	Dried plus spray
Lint moisture----------percent	5.7	2.8	3.3	5.5
Lint foreign matter----------percent	2.9	2.2	2.2	3.0
Lint grade----------designation	SLM	M	M	SLM
Staple length---------32ds of an inch	34	34	34	34
Pressley strength, 1/8-inch gage----------grams/tex	21.1	20.0	20.1	20.8
Micronaire----------reading	4.6	4.7	4.7	4.8
Upper quartile length----------inches	1.21	1.17	1.19	1.22
Mean length----------inches	.99	.93	.96	1.01
Coefficient of variation------percent	31	34	32	30
Fibers 1/2-inch and shorter---percent	9.7	12.7	10.7	8.7
1/2 to 1 inch----------percent	30.1	36.2	31.6	28.0
1 inch and longer----------percent	60.2	51.3	57.7	63.3

Table 6 shows that staple length, strength, and Micronaire were unaffected by drying followed by adequate moisture restoration. However, the ginning process does not affect bundle strength or Micronaire, and these figures are shown only to more fully describe the cotton.

The usual pattern for overdrying is reflected in all of the important fiber length properties. Upper quartile length was reduced the equivalent of more than 1/32 of an inch because of overdrying. The vapor-treated lot was shortened only about one-half of a staple length, and the sprayed lot was shortened none at all. There are no contradictions in any of the fiber length measurements, indicating that when moisture is added to cottons that are quite dry, fiber breakage during ginning can be drastically reduced.

The effects of moisture content on the various length properties are reflected in the spinning performance (table 7). Ends-down per 1,000 spindle hours ranged from 65 with no drying to 73 when the cotton was dried. When moisture was added prior to ginning, the ends-down dropped back to 60 and 66, respectively, for vapor and sprayed lots. Break factor and single-strand yarn strength tests followed the same pattern as the length measurements for the various treatments. Yarn appearance was virtually unaffected. Although the results of the second year's tests are not complete, it is believed that they will follow the same general pattern.

Table 7. Effect of drying and moisture restoration on spinning

Item	Treatment			
	No drying	Drying	Drying and vapor	Drying and spray
Lint moisture----------percent	5.7	2.8	3.3	5.5
Yarn size----------number	38.2	38.6	38.7	38.4
Ends-down, per 1,000 spindle hours---	65	73	60	66
Break factor----------	1869	1692	1761	1890
Yarn appearance----------index	105	105	103	101
Single strand strength----------grams	191	174	178	191

CONCLUSIONS

(1) Reduced spinning performance of overdried cotton appears to be primarily due to fiber breakage.

(2) Cotton should never be overdried in an effort to obtain grade. It producers and ginners follow research recommendations, they can obtain satisfactory grades without sacrificing the use value of the cotton.

(3) Intentional overdrying of cotton and restoring the moisture to it before ginning is not beneficial to the producer. It is believed but not yet proved that this procedure causes some irreversible change in the cotton fiber.

(4) Cotton having a fiber moisture content of less than 6 to 7 percent should not be gin dried. Instead, moisture should be added before cotton reaches the fiber-seed-separation process in order to improve the ginning quality of the cotton.

(5) Operating difficulties and rough preparation often result when cotton is ginned with fiber moisture content above 8 percent.

(6) To preserve fiber quality, research indicates that there is an optimum percentage of moisture that cotton should have for the various processes used in ginning just as there is for the processes used in manufacturing.

Predictions are that moisture controls will be available on various kinds of equipment used in ginning within a few years, that this equipment will be in common usage, and that its use will improve the quality of raw material for the textile industry.

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